

1 Claims

1 1. A method of etching a high aspect ratio opening in a substrate, the method  
2 comprising the steps of:

3 etching the substrate with a first plasma formed using a first gaseous mixture  
4 including a bromine containing gas, an oxygen containing gas and a first  
5 fluorine containing gas, the etching step simultaneously producing a sidewall  
6 passivating deposit;

7 thinning the sidewall passivating deposit with a second plasma formed using a  
8 second gaseous mixture including a non-halogenated hydrogen containing gas  
9 and a second fluorine containing gas; and

10 repeating the steps of etching and thinning to produce a desired depth for the  
11 opening.

1 2. The method of claim 1 wherein the non-halogenated hydrogen containing gas is  
2 selected from the group consisting of silanes and ammonia.

1 3. The method of claim 1 wherein the non-halogenated hydrogen containing gas is  
2 monosilane or disilane.

1 4. The method of claim 1 wherein the second gaseous mixture also includes a  
2 bromine containing gas.

1 5. The method of claim 4 wherein the bromine containing gas is provided to the  
2 second gaseous mixture during the thinning step at flow rate that is less than the flow  
3 rate of the bromine containing gas provided to the first gaseous mixture during the  
4 etching step.

1 6. The method of claim 1 wherein the second gaseous mixture also includes an  
2 oxygen containing gas.

1 7. The method of claim 1 wherein the step of etching is repeated at equally spaced  
2 intervals and the step of thinning the sidewall passivating deposit is also repeated at  
3 equally spaced intervals between the equally spaced etching steps.

1 8. The method of claim 1 wherein the bromine containing gas in the first gaseous  
2 mixture is HBr.

1 9. The method of claim 1 wherein the first and second fluorine containing gases  
2 are selected from the group consisting of  $\text{NF}_3$ ,  $\text{SF}_6$ , elemental fluorine and mixtures  
3 thereof.

1 10. The method of claim 9 wherein the first and second fluorine containing gases  
2 are  $\text{NF}_3$ .

1 11. The method of claim 1 wherein the steps of etching and thinning the sidewall  
2 passivating deposit are repeated at least twice.

1 12. The method of claim 1 wherein the etching and thinning steps occur in a single  
2 plasma reactor without removing the substrate from the plasma reactor.

1 13. The method of claim 1 wherein the steps of etching and thinning are repeated  
2 until the opening has a depth at least 15 times greater than a width of the opening.

1 14. The method of claim 1 wherein the steps of etching and thinning are repeated  
2 until the opening has a depth at least 40 times greater than a width of the opening.

1 15. The method of claim 1 wherein the bromine containing gas in the step of etching  
2 the substrate is HBr and the step of etching the substrate includes providing the HBr gas  
3 at a flow rate from 100 – 300 sccm.

1 16. The method of claim 1 wherein the first fluorine containing gas in the step of  
2 etching the substrate is  $\text{NF}_3$  and the step of etching the substrate includes providing the  
3  $\text{NF}_3$  gas at a flow rate from 4 – 25 sccm.

1 17. The method of claim 1 wherein the oxygen containing gas in the step of etching  
2 the substrate is  $\text{O}_2$  or  $\text{O}_2$  mixed with helium and the step of etching the substrate  
3 includes providing the oxygen containing gas at a flow rate of up to 25 sccm.

1 18. The method of claim 1 wherein the second fluorine containing gas in the step of  
2 thinning the sidewall passivating deposit is  $\text{SF}_6$  and the step of thinning the sidewall  
3 passivating deposit includes providing the second fluorine containing gas at a flow rate  
4 of up to 25 sccm.

1 19. The method of claim 1 wherein the non-halogenated hydrogen containing gas in  
2 the step of thinning the sidewall passivating deposit is silane and the step of thinning the  
3 sidewall passivating deposit includes providing the silane at a flow rate of up to 250  
4 sccm.

1 20. A method of etching a high aspect ratio opening in a substrate, the method  
2 comprising the steps of:  
3 etching the substrate with a first plasma formed using a first gaseous mixture  
4 including a bromine containing gas, an oxygen containing gas and a first  
5 fluorine containing gas selected from the group consisting of  $\text{NF}_3$ ,  $\text{SF}_6$ ,

6 elemental fluorine and mixtures thereof, the etching step simultaneously  
7 producing a sidewall passivating deposit;  
8 thinning the sidewall passivating deposit with a second plasma formed using a  
9 second gaseous mixture including a non-halogenated hydrogen containing gas  
10 selected from the group consisting of silane and ammonia, a second fluorine  
11 containing gas selected from the group consisting of  $\text{NF}_3$ ,  $\text{SF}_6$ , elemental  
12 fluorine and mixtures thereof, and at least one additional gas selected from the  
13 group consisting of a bromine containing gas and an oxygen containing gas; and  
14 repeating the steps of etching and thinning to produce a desired depth for the  
15 opening.